



### Santa Clara Valley Urban Runoff Pollution Prevention Program

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# IV

## STORMWATER TREATMENT CONTROL SIZING CRITERIA

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*The goal of this Chapter is to provide guidance on appropriately sizing stormwater treatment BMPs to meet the requirements of Provision C.3.*

### IV.1 INTRODUCTION

The sizing of the stormwater treatment BMPs selected as described in Chapter III must meet criteria identified in the NPDES permit's Provision C.3.d. This chapter explains the hydraulic sizing criteria that are required by the permit. Worksheets and sizing curves to assist municipal staff and project designers in sizing various treatment systems are provided.

#### **Volume-Based Versus Flow-Based Versus Combination BMPs**

The two (2) basic stormwater treatment removal processes are volume-based and flow-based BMPs. Volume-based BMPs detain stormwater for a certain period and treat primarily through settling and infiltration. Flow-based BMPs treat pollutants from a moving stream of water through filtration, infiltration, and/or biological processes. This section does not address the sizing of a treatment system that will be used for both volume and flow control, as may be required by the Program's Hydromodification Management Plan (HMP). The design of dual-purpose systems will be addressed in the completed HMP report and added to Chapter V of this Handbook at a future date.

Appendix F describes the development of numeric sizing criteria for stormwater treatment systems for conditions in the Santa Clara Basin, as required in the Program's NPDES Permit Provision C.3.d. It applies the different criteria to several examples for a comparison of the results. The Program acknowledges the assistance of GeoSyntec Consultants, for the technical analyses and report (GeoSyntec Consultants, 2003) that form the basis of this section.

### IV.2 HYDRAULIC SIZING CRITERIA

The following are the hydraulic sizing criteria required by Provision C.3.d. The name assigned to each criterion is consistent with the nomenclature used in the 2003 California Best Management Practice (BMP) Manual for New Development and Redevelopment (CASQA, 2003) and is given in bold in the parentheses following each criterion.

**C.3.d.i. Volume Hydraulic Design Basis:** Volume-based treatment BMPs are designed to treat a volume of runoff, which is detained for a certain period of time to effect settling of solids and associated pollutants. Examples of volume-

based controls include wet ponds, detention basins, constructed wetlands, and bioretention systems (see Attachment III-2 for additional examples). Treatment BMPs<sup>1</sup> whose primary mode of action depends on volume capacity, such as detention/retention units or infiltration structures shall be designed to treat storm water runoff equal to:

- The maximum stormwater quality capture volume for the area, based on historical rainfall records, determined using the formula and volume capture coefficients set forth in *Urban Runoff Quality Management, WEF Manual of Practice No. 23 and ASCE Manual of Practice No. 87, (1998)*, pages 175-178 (**URQM Approach**); or
- The volume of annual runoff required to achieve eighty percent (80%) or more capture, determined in accordance with the methodology set forth in Appendix D of the *California Stormwater Best Management Practices Handbook, (1993)* using local rainfall data. (**CA Stormwater BMP Handbook Volume Approach**).

***C.3.d.ii. Flow Hydraulic Design Basis:*** Flow-based treatment BMPs treat water on a continuous flow basis. Examples include vegetated swales, media filters, hydrodynamic separators and screened systems.<sup>2</sup> Treatment BMPs whose primary mode of action depends on flow capacity, such as swales, sand filters, or wetlands, shall be sized to treat:

- Ten percent (10%) of the 50-year peak flow rate (**Factored Flood Flow Approach**); or,
- The flow of runoff produced by a rain event equal to or at least two (2) times the 85<sup>th</sup> percentile hourly rainfall intensity for the applicable area, based on historical records of hourly rainfall depths (**CA Stormwater BMP Handbook Flow Approach**); or,
- The flow of runoff from a rain event equal to at least 0.2 inches per hour intensity (**Uniform Intensity Approach**).

### **IV.3 RECOMMENDATIONS**

Stormwater treatment BMPs designed using any of the sizing methods specified in Permit Provision C.3.d., when properly applied, will be in compliance with the NPDES permit's requirements. However, the various sizing methods have advantages and disadvantages to their use, and local agencies may wish to specify a preference for particular methods in order to standardize development project submittals. Therefore, Table IV.1 presents a summary of the advantages and disadvantages of the methods. The recommended sizing methods are also discussed following this summary.

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<sup>1</sup> For the purpose of this section, a stormwater best management practice (BMP) is the same as a stormwater treatment measure, device, or control.

<sup>2</sup> For clarification, flow-based treatment BMPs differ from flow control BMPs, which are used to limit the volume and rate of discharge from a development site, such as may be required by the Program's HMP (see Chapter V).

**Table IV.1 -- Advantages and Disadvantages of Alternative Sizing Methods**

<b>Volume Based Methods</b>		
	<b>Advantages</b>	<b>Disadvantages</b>
1) Urban Runoff Quality Management (URQM) Method	Based on modeling and regression analysis using long-term rainfall records in six cities including San Francisco. Takes into account drain time. Easy to apply.	Does not simulate performance under local rainfall patterns, but estimates volume based on average storm event size. Does not consider soil type or slope.
2) CA Stormwater BMP Handbook Volume Method (adapted for Santa Clara Valley using SWMM Model)	More comprehensive method. Takes into account drain time, slope, and soil types. Based on continuous simulation of detention storage, outflow, and bypass using local long-term rainfall records.	More complex method of the two candidate methods. Curves are provided that should cover most applications.
<b>Flow Based Methods</b>		
	<b>Advantages</b>	<b>Disadvantages</b>
1) Factored Flood Flow Approach (10% of 50-year rainfall intensity)	Intensity-duration-frequency curves are very familiar to most engineers. Takes into account local rainfall conditions.	Not based on achieving any given level of treatment of small storms. Sensitive to time of concentration estimate, which could make it more difficult for development review agency.
2) CA Stormwater BMP Handbook Flow Approach (2 times 85th percentile rainfall intensity)	Takes into account local rainfall conditions.	Some question regarding appropriateness of factor of 2.
3) Uniform Intensity Approach (0.2 inches/hr)	Simplest of methods.	Does not take into account local rainfall patterns and statistics.

For volume-based controls, the adapted CA Stormwater BMP Handbook Volume Method is recommended because it takes into account rainfall characteristics, percent imperviousness, drainage time, soil infiltration conditions, and slope. All of these factors can be relatively easily determined for a site, and the design curves provided in this report (Attachment IV-1) should be sufficient for sizing basins and other volume-based controls. In addition, the method simulates the operation of a basin under realistic conditions, and it is reasonable to assume that

basins designed using this method will achieve the desired percent capture specified in permit Provision C.3.d. Lastly, this method explicitly incorporates a drain time that allows an appropriate level of treatment while avoiding vector control concerns.

For flow based controls, the CA Stormwater BMP Handbook Flow Method is recommended, using the values estimated for each of the rain gages. This method is based on local rainfall data and achieving treatment of small storms consistent with the permit requirements.

Attachment IV-1 contains worksheets and sizing curves to assist municipal staff and development project proponents in sizing various treatment systems using all five (5) of the alternative sizing methods. Attachment IV-2 contains worksheets completed for an example of a single-family residential project in Santa Clara Valley.

#### **IV.4. REFERENCES**

California Stormwater Quality Association, 2003. Stormwater Best Management Practice Handbook, New Development and Redevelopment, January.

Camp Dresser & McKee, 2003. Using Site Design Techniques to Meet Development Standards for Stormwater Quality. Prepared for the Bay Area Stormwater Management Agencies Association. May.

GeoSyntec Consultants, 2003. Sizing Criteria for Stormwater Treatment. Draft Report. Prepared for the Santa Clara Valley Urban Runoff Pollution Prevention Program and the Santa Clara Valley Water District.

Water Environment Federation (WEF) Manual of Practice No. FD-20 / American Society of Civil Engineers (ASCE) Manual and Report of Engineering Practice No. 77, 1992. Design and Construction of Urban Stormwater Management Systems.

Water Environment Federation (WEF) Manual of Practice No. 23 / American Society of Civil Engineers (ASCE) Manual and Report of Engineering Practice No. 87, 1998. Urban Runoff Quality Management.

Several figures and tables are provided in Attachment IV-1 to assist in selecting and designing BMPs.

Figure 1: Mean Annual Precipitation Depths and Soil Texture for the Santa Clara Basin

Figures 2 and 3: Unit Basin Volumes

Figure 4: Rain Intensity-Frequency-Duration Curves



## **ATTACHMENT IV-1**

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### **Sizing Criteria Worksheets**

#### **TABLES**

Table 1 – Examples Of Volume-Based And Flow-Based Controls

Table 2 – Precipitation Data for Four Reference Gages

Table 3a – Estimated Runoff Coefficients for Various Surfaces During Small Storms (CDM, 2003)

Table 3b – Estimated Composite Runoff Coefficients for Small Storms by Land Use (WEF/ASCE, 2003)

#### **FIGURES**

Figure 1 – Mean Annual Precipitation Depths and Soil Texture for the Santa Clara Basin

Figure 2 – Unit Basin Volumes for 80% Capture, Assumed slope = 1%

Figure 3 – Unit Basin Volumes for 80% Capture, Assumed slope = 15%

Figure 4 – Rain Intensity-Frequency-Duration Curves



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## ***C.3 Stormwater Handbook***

### **Attachment IV-1 Sizing Criteria Worksheets**

These worksheets are designed to assist municipal staff and development project proponents in sizing stormwater treatment controls. Figures used in the computations can be found at the back of these worksheets.

#### **I. Type of Treatment Measure Proposed for Project**

1. Does the treatment measure (or part of a series of measures) operate based on the volume of water treated (i.e., detains an amount of runoff for a certain amount of time to allow solids and pollutants to settle to the bottom)? (See Table 1 for examples.)

\_\_\_ Yes

\_\_\_ No

*If Yes, continue to Section II.—Sizing for Volume-Based Treatment Controls on page 2.*

*If No, continue to next question.*

2. Does the treatment measure (or part of a series of measures) operate based on continuous flow of runoff through the device? (See Table 1 for examples.)

\_\_\_ Yes

\_\_\_ No

*If Yes, continue to Section III.—Sizing for Flow-Based Treatment Controls on page 8.*

**Table 1: Examples Of Volume-Based And Flow-Based Controls**

<b>Volume-based Controls</b>	<b>Flow-based Controls</b>
Extended detention (dry) ponds	Vegetated swales
Wet ponds	Vegetated buffer strips
Infiltration trench	Media filters
Infiltration basin	Hydrodynamic separators
Bioretention areas	Wet vaults
Constructed wetlands	Other proprietary treatment devices

**Attachment IV-1**  
**Sizing for Volume-Based Treatment Controls**

**II. Sizing for Volume-Based Treatment Controls**

The SCVURPPP Permit Provision C.3.d allows two methods for sizing volume-based controls—the Urban Runoff Quality Management method (URQM Method) or the California Stormwater Best Management Practice<sup>1</sup> (BMP) Handbook Volume Method. Steps for applying these methods are presented in Sections A and B below.

*Section A.— Sizing Volume-Based Treatment Controls based on the Urban Runoff Quality Management<sup>1</sup>, Approach (URQM Approach)*

The equations used in this method are:

$$P_o = (a * C_w) * P_6$$

$$C_w = 0.858i^3 - 0.78i^2 + 0.774i + 0.04$$

Where:

$P_o$  = maximized detention storage volume (inches over the drainage area to the BMP)

$a$  = regression constant (unitless)

$C_w$  = watershed runoff coefficient (unitless)<sup>2</sup>

$P_6$  = mean storm event precipitation depth (inches);

$i$  = watershed impervious ratio (range: 0-1)

Step 1. Determine the drainage area for the BMP,  $A$  =  acres

Step 2. Determine the watershed impervious ratio, “ $i$ ”, which is the amount of impervious area in the drainage area to the BMP divided by the drainage area, or the percent of impervious area in the drainage area divided by 100.

a. Estimate the amount of impervious surface (rooftops, hardscape, streets, and sidewalks, etc.) in the area draining to the BMP =  acres

b. Calculate the watershed impervious ratio,  $i$ :

$i$  = amount of impervious area (acres)/drainage area for the BMP (acres)

$i$  = (Step 2.a.)/(Step 1) =  (range: 0-1)

Percent impervious area =  $i/100$  =  %

<sup>1</sup> For the purpose of this worksheet, a stormwater best management practice, or BMP, is the same as a stormwater treatment measure or device.

<sup>2</sup> For the purpose of this worksheet, the watershed runoff coefficient is notated as “ $C_w$ ” to avoid confusion with the runoff coefficient “ $C$ ” used in the Rational Method.

**Attachment IV-1  
Sizing for Volume-Based Treatment Controls**

*Section A.— URQM Approach (continued)*

Step 3. Determine the watershed runoff coefficient, “C<sub>w</sub>”, using the following equation:

$$C_w = 0.858i^3 - 0.78i^2 + 0.774i + 0.04, \text{ using “}i\text{” from Step 2.b.}$$

$$C_w = \boxed{\phantom{000000}}$$

Step 4. Find the mean annual precipitation at the site (MAP<sub>site</sub>). To do so, estimate where the site is on Figure 1 and estimate the mean annual precipitation in inches from the rain line (isopleth) nearest to the project site.<sup>3</sup>

$$\text{Mean annual precipitation at the site, MAP}_{\text{site}} = \boxed{\phantom{000000}}$$

*(Each line on the figure, called a rainfall isopleth, indicates locations where the same amount of rainfall falls on average each year (e.g., the isopleth marked 14 indicates that areas crossed by this line average 14 inches of rainfall per year). If the project location is between two lines, estimate the mean annual rainfall depending on the location of the site.)*

Step 5. Identify the reference rain gage closest to the project site from the following list.

**Table 2: Precipitation Data for Four Reference Gages**

<b>Gages</b>	<b>Mean Annual Precipitation (MAP<sub>gage</sub>) (in)</b>	<b>Mean Storm Event Precipitation (P<sub>6</sub>)<sub>gage</sub> (in)</b>
San Jose Airport	13.9	0.512
Palo Alto	13.7	0.522
Gilroy	18.2	0.684
Morgan Hill	19.5	0.760

Select the MAP<sub>gage</sub> and the mean storm precipitation (P<sub>6</sub>)<sub>gage</sub> for the reference gage, and use them to determine (P<sub>6</sub>)<sub>site</sub> for the project site in Step 6.

$$\text{MAP}_{\text{gage}} = \boxed{\phantom{000000}}$$

$$(P_6)_{\text{gage}} = \boxed{\phantom{000000}}$$

<sup>3</sup> Check with the local municipality to determine if more detailed maps are available for locating the site and estimating MAP.



**Attachment IV-1**  
**Sizing for Volume-Based Treatment Controls**

*Section A.— URQM Approach (continued)*

Step 6. Calculate the mean storm event precipitation depth at the project site, called  $(P_6)_{\text{site}}$ . Multiply the mean storm event precipitation depth for the rain gage chosen by a correction factor, which is the ratio of the mean annual precipitation at the site ( $\text{MAP}_{\text{site}}$ ) to the mean annual precipitation at the rain gage ( $\text{MAP}_{\text{gage}}$ ).

$$(P_6)_{\text{site}} = (P_6)_{\text{gage}} * (\text{MAP}_{\text{site}}) / (\text{MAP}_{\text{gage}}).$$

$$(P_6)_{\text{site}} = \text{Mean Event Precipitation } (P_6)_{\text{gage}} (\text{Step 5}) * (\text{MAP}_{\text{site}}) (\text{Step 4}) / (\text{MAP}_{\text{gage}}) (\text{Step 5}).$$

$$P_6 \text{ site} = \boxed{\phantom{000000}} \text{ inches}$$

Step 7 Find “a”, the regression constant (unitless)<sup>4</sup>:

$a = 1.963$  for a 48-hour drain time

$a = 1.582$  for a 24-hour drain time

$a = 1.312$  for a 12-hour drain time

$$a = \boxed{\phantom{000000}}$$

Recommendation: Use a 48-hour drain time for detention basins and 24-hour drain time for pervious paving.

Step 8 Determine the maximized detention storage volume  $P_o$ :

$$P_o = (a * C_w) * P_6$$

$$P_o = (\text{Step 7} * \text{Step 3}) * (\text{Step 6})$$

$$P_o = \boxed{\phantom{000000}} \text{ inches}$$

Step 9 Determine the volume of the runoff to be treated from the drainage area to the BMP (i.e., the BMP design volume):

$$\text{Design volume} = P_o * A = (\text{Step 8}) * (\text{Step 1}) * 1 \text{ foot}/12 \text{ inches}$$

$$\text{Design Volume} = \boxed{\phantom{000000}} \text{ acre-feet}$$

<sup>4</sup> WEF Manual of Practice No. 23 and the ASCE Manual of Practice No. 87 (1998), pages 175-178.

**Attachment IV-1  
Sizing for Volume-Based Treatment Controls**

*Section B — Sizing Volume-Based Treatment Controls based on the Adapted California Stormwater BMP Handbook Approach*

The equation that will be used to size the BMP is:

$$\text{BMP Volume} = (\text{Correction Factor}) \times (\text{Unit Storage}) \times (\text{Drainage Area to the BMP})$$

Step 1. Determine the drainage area for the BMP, A =  acres

Step 2. Determine percent imperviousness of the drainage area:

- a. Estimate the amount of impervious surface (rooftops, hardscape, streets, and sidewalks, etc.) in the area draining to the BMP:  acres
- b. % impervious area = (amount of impervious area / drainage area for the BMP) \* 100  
% impervious area = (Step 2a. / Step 1) \* 100  
% impervious area =  %

Step 3. Determine from Figure 1 the mean annual precipitation (MAP<sub>site</sub>) at the project site location: (see Section II. Step 4 for more explanation.)

$$\text{MAP}_{\text{site}} = \text{  inches}$$

Step 4 Identify the reference rain gage closest to the project site from the following list and record the MAP<sub>gage</sub>:

$$\text{MAP}_{\text{gage}} = \text{  inches}$$

Reference Rain Gages	Mean Annual Precipitation (MAP <sub>gage</sub> ) (in)
San Jose Airport	13.9
Palo Alto	13.7
Gilroy	18.2
Morgan Hill	19.5

**Attachment IV-1**  
**Sizing for Volume-Based Treatment Controls**

*Section B—Adapted California Stormwater BMP Handbook Approach (continued)*

Step 5 Determine the rain gage correction factor for the precipitation at the site using the information from **Step 3** and **Step 4**.

$$\text{Correction Factor} = \text{MAP}_{\text{site}} (\text{Step 3}) / \text{MAP}_{\text{gage}} (\text{Step 4})$$

$$\text{Correction Factor} = \boxed{\phantom{000}}$$

Step 6. Identify representative soil type for the BMP drainage area.

- a) Identify from Figure 1, the soil type that is representative of the pervious portion of the project shown here in order of increasing infiltration capability:

\_\_\_\_ Clay                      \_\_\_\_ Sandy Clay                      \_\_\_\_ Clay Loam  
\_\_\_\_ Silt Loam                      \_\_\_\_ Loam

- b) Does the site planning allow for protection of natural areas and associated vegetation and soils so that the soils outside the building footprint are not graded/compacted? ☐

If your answer is no, and the soil will be compacted during site preparation and grading, the soil's infiltration ability will be decreased. Modify your answer to a soil with a lower infiltration rate (e.g., Silt Loam to Clay Loam or Clay).

Modified soil type:

7. Determine the average slope for the drainage area for the BMP:  %

8. Determine the unit basin storage volume from sizing curves.

- a) Slope  $\leq$  1%

Use the figure entitled "Unit Basin Volume for 80% Capture, 1% Slope" corresponding to the nearest rain gage: Figure 2-A, B, C, or D for San Jose, Palo Alto, Gilroy and Morgan Hill, respectively. Find the percent imperviousness of the drainage area (see answer to **Step 2**, above) on the x-axis. From there, find the line corresponding to the soil type (from **Step 6**), and obtain the unit basin storage on the y-axis.

$$\text{Unit Basin Storage for 1\% slope (UBS}_{1\%}) = \boxed{\phantom{000}} \text{ (inches)}$$

- b) Slope  $\geq$  15%

Use the figure entitled "Unit Basin Volume for 80% Capture, 15% Slope" corresponding to the nearest rain gage: Figure 3-A, B, C, or D for San Jose, Palo Alto, Gilroy and Morgan Hill, respectively. Find the percent imperviousness of the drainage area (see answer to **Step 2**, above) on the x-axis. From there, find the line corresponding to the soil type (from **Step 6**), and obtain the unit basin storage on the y-axis.

$$\text{Unit Basin Storage for 15\% slope (UBS}_{15\%}) = \boxed{\phantom{000}} \text{ (inches)}$$

**Attachment IV-1**  
**Sizing for Volume-Based Treatment Controls**

*Section B—Adapted California Stormwater BMP Handbook Approach (continued)*

- c) Slope > 1% and < 15%

Find the unit basin volumes for 1% and 15% using the techniques in **Steps 8a** and **8b** and interpolate by applying a slope correction factor per the following formula:

$$\begin{aligned} \text{UBS}_x &= \text{UBS}_{1\%} + (\text{UBS}_{15\%} - \text{UBS}_{1\%}) * (x\% - 1\%) / (15\% - 1\%) \\ &= (\text{Step 8a}) + (\text{Step 8b} - \text{Step 8a}) * (x\% - 1\%) / (15\% - 1\%) \end{aligned}$$

Where  $\text{UBS}_x$  = Unit Basin Storage volume for drainage area of intermediate slope, x %

$$\begin{aligned} \text{Unit Basin Storage volume (USB}_x) &= \text{[ ] (inches)} \\ &\text{(corrected for slope of site)} \end{aligned}$$

9. Size the BMP, using the following equation:

BMP Volume = Rain Gage Correction Factor \* Unit Basin Storage Volume \* Drainage Area

BMP Volume = (**Step 5**) \* (**Step 8** unit storage) \* (**Step 1** Drainage area) \* 1 foot/12 in.

$$\text{BMP Volume} = \text{[ ] acre-feet}$$

### **III. Sizing for Flow-based Treatment Controls**

The SCVURPPP permit allows three methods for sizing flow-based treatment measures—the Factored Flood Flow Method (10% of the 50-year peak flow rate); the California BMP Handbook Method (the flow produced by a rain event equal to at least 2 times the 85<sup>th</sup> percentile hourly rainfall intensity); or the Uniform Intensity Method (the flow produced by a rain event equal to at least 0.2 inches/hour intensity). Tables 3a and 3b are utilized in each of the three methods.

**Table 3a – Estimated Runoff Coefficients for Various Surfaces  
During Small Storms (CDM, 2003)**

<b>Surface</b>	<b>Runoff Coefficient (C Factor)</b>
Concrete	0.80
Asphalt	0.70
Pervious Concrete	0.60
Cobbles	0.60
Pervious Asphalt	0.55
Natural Stone (without grout)	0.25
Turf Block	0.15
Brick (without grout)	0.13
Unit Pavers on Sand	0.10
Crushed Aggregate	0.10
Grass	0.10
Roofs (from WEF/ASCE, 1992)	0.75

Notes: The above C-factors were estimated by selecting the lower range of the best available C-factor for each paving surface. These C-factors are only appropriate for small storm treatment BMP design, and should not be used for flood control sizing. Where available, locally developed small storm C-factors for various surfaces should be used.

**Table 3b – Estimated Composite Runoff Coefficients for  
Small Storms by Land Use (WEF/ASCE, 2003)**

<b>Description of Area</b>	<b>Runoff Coefficient (C Factor)</b>
Business: Neighborhood	0.50
Downtown	0.70
Residential: Single Family	0.30
Multi-unit, detached	0.40
Apartment	0.50
Multi-unit, attached	0.60
Industrial: Light	0.50
Heavy	0.60
Parks, cemeteries	0.10
Playgrounds	0.20
Unimproved	0.10

Notes: The above C-factors were estimated by selecting the lower range of the runoff coefficients listed for various land uses in WEF/ASCE, 1992. Where available, locally developed small storm C-factors for various land uses should be applied.

Section A — Sizing Flow-Based Treatment Controls based on the Factored Flood Flow Approach

This method uses the Rational Method equation to determine the design flow, using a design intensity that is 10 % of the intensity for the 50-year return period found on the local intensity-duration-frequency (IDF) curve:

$$Q = CIA$$

Where:

Q is the design flow in cubic feet per second (cfs),

C is the drainage area runoff coefficient,

I is the design intensity (in/hr), and

A is the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A =  acres

Step 2 Determine the runoff coefficient, C =  from Table 3a or 3b

It is more accurate to compute an area-weighted “C-factor” based on the surfaces in the drainage area (Table 3a), if possible, than to assume a composite “C-factor” such as those in Table 3b, especially for small drainage areas.

Step 3 Find the time of concentration ( $t_c$ ) for the site (i.e. the travel time from the most remote portion of the BMP drainage area to the BMP). (Check with local agency’s Engineering Department for standard or accepted methods of computing  $t_c$ ).

$$t_c = \text{Time of overland flow} + \text{time in drainage pipe} = \text{  hrs}$$

Step 4 Using the time of concentration as the duration, use Figure 4 to determine the intensity for the 50-year storm (IDF curve) (in/hr). \_\_\_\_\_

$$\text{intensity for the 50-year storm} = \text{  in/hr}$$

Step 5 The design intensity (I) will be 10% of the intensity obtained from the IDF curve (intensity for the 50-year storm).

$$I = (\text{Step 4} * 0.10) = \text{  in/hr}$$

Step 6 Determine the design flow (Q) using the Rational Method equation:

$$Q = C * I * A$$

$$Q = (\text{Step 2}) * (\text{Step 5}) * (\text{Step 1})$$

$$Q = \text{ _____ acres-in/hr}$$

$$\text{Design Flow, } Q = \text{  cfs}^5$$

<sup>5</sup> No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) \* (43,560 s.f./acre) \* (1ft/12 in) \* (1hr/3600 sec)  $\approx$  1 ft<sup>3</sup>/ sec or cfs.

**Attachment IV-1  
Sizing for Flow-Based Treatment Controls**

*Section B—Sizing Flow-Based Treatment Controls based on the California Stormwater BMP Handbook Flow Approach*

This method uses the Rational Method equation to determine the design flow:

$$Q = CIA$$

Where:

Q = the design flow in cubic feet per second (cfs),

C = the drainage area runoff coefficient,

I = the design intensity (in/hr), and

A = the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A =  acres

Step 2 Determine the runoff coefficient, C =  from Table 3a or 3b

It is more accurate to compute an area-weighted “C-factor” based on the surfaces in the drainage area (Table 3a), if possible, than to assume a composite “C-factor” such as those in Table 3b, especially for small drainage areas.

Step 3. Determine from Figure 1 the mean annual precipitation (MAP<sub>site</sub>) at the project site location: (see Section II. Step 4 for more explanation.)

$$MAP_{site} = \text{inches}$$

Step 4 Identify the reference rain gage closest to the project site from the following list and record the MAP<sub>gage</sub>:

$$MAP_{gage} = \text{inches}$$

<b>Reference Rain Gages</b>	<b>Mean Annual Precipitation (MAP<sub>gage</sub>) (in)</b>
San Jose Airport	13.9
Palo Alto	13.7
Gilroy	18.2
Morgan Hill	19.5

Step 5 Determine the rain gage correction factor for the precipitation at the site using the information from **Step 3** and **Step 4**.

$$\text{Correction Factor} = MAP_{site} / MAP_{gage} = (\text{Step 3}) / (\text{Step 4})$$

$$\text{Correction Factor} = \text{inches}$$

**Attachment IV-1  
Sizing for Flow-Based Treatment Controls**

*Section B—California Stormwater BMP Handbook Flow Approach (continued)*

Step 6 Select the design intensity, I, for the reference gage closest to the site from the following list:

I, Design Rainfall Intensity =  in/hour

<b>Gages</b>	<b>85<sup>th</sup> Percentile Hourly Rainfall Intensity (in/hr)</b>	<b>Design Rainfall Intensity (I) (in/hr)</b>
San Jose Airport	0.087	0.17
Palo Alto	0.096	0.19
Gilroy	0.11	0.21
Morgan Hill	0.12	0.24

The design intensity is twice the 85<sup>th</sup> percentile Hourly Rainfall Intensity.

Step 7. Determine the corrected design rainfall intensity (I) for the site:

Design intensity (site) = Correction factor \* Design rainfall intensity for closest rain gage

Design intensity (site) = (Step 5) \* (Step 6) =  in/hr

Step 8. Determine the design flow (Q) using the Rational Method equation:

$$Q = C * I * A$$

$$Q = (\text{Step 2}) * (\text{Step 7}) * (\text{Step 1})$$

$$Q = \text{_____ acres-in/hr}$$

$$\text{Design Flow, } Q = \text{_____ cfs}^6$$

<sup>6</sup> No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) \* (43,560 sq.ft/acre) \* (1ft/12 in) \* (1hr/3600 sec)  $\approx$  1 ft<sup>3</sup>/ sec or cfs.



**Attachment IV-1**  
**Sizing for Flow-Based Treatment Controls**

*Section C.—Sizing Flow-Based Treatment Controls based on the Uniform Intensity Approach*

This method uses the Rational Method equation:

$$Q = CIA$$

Where:

Q is the design flow in cubic feet per second (cfs),  
C is the drainage area runoff coefficient,  
I is the design intensity (in/hr), and  
A is the drainage area for the BMP (acres)

Step 1. Determine the drainage area for the BMP, A =  acres

Step 2 Determine the runoff coefficient, C =  from Table 3a or 3b

It is more accurate to compute an area-weighted “C-factor” based on the surfaces in the drainage area (Table 3a), if possible, than to assume a composite “C-factor” such as those in Table 3b, especially for small drainage areas.

Step 3 Use a design intensity of **0.2 in/hr** for “I” in the Q=CIA equation.

$$I = \text{0.2 in/hour}$$

Step 4 Determine the design flow (Q) using Q = CIA

$$Q = C * I * A$$

$$Q = (\text{Step 2}) * (0.2 \text{ in/hr}) * (\text{Step 1})$$

$$Q = \text{_____} \text{ acres-in/hr}$$

$$\text{Design Flow, } Q = \text{_____} \text{ cfs}^7$$

<sup>7</sup> No conversion factor for correct units is needed for the rational formula because (1 acre-in/hr) \* (43,560 sq.ft/acre) \* (1ft/12 in) \* (1hr/3600 sec) ≈ 1 ft<sup>3</sup>/ sec or cfs.

Figure 1 Soil and Precip

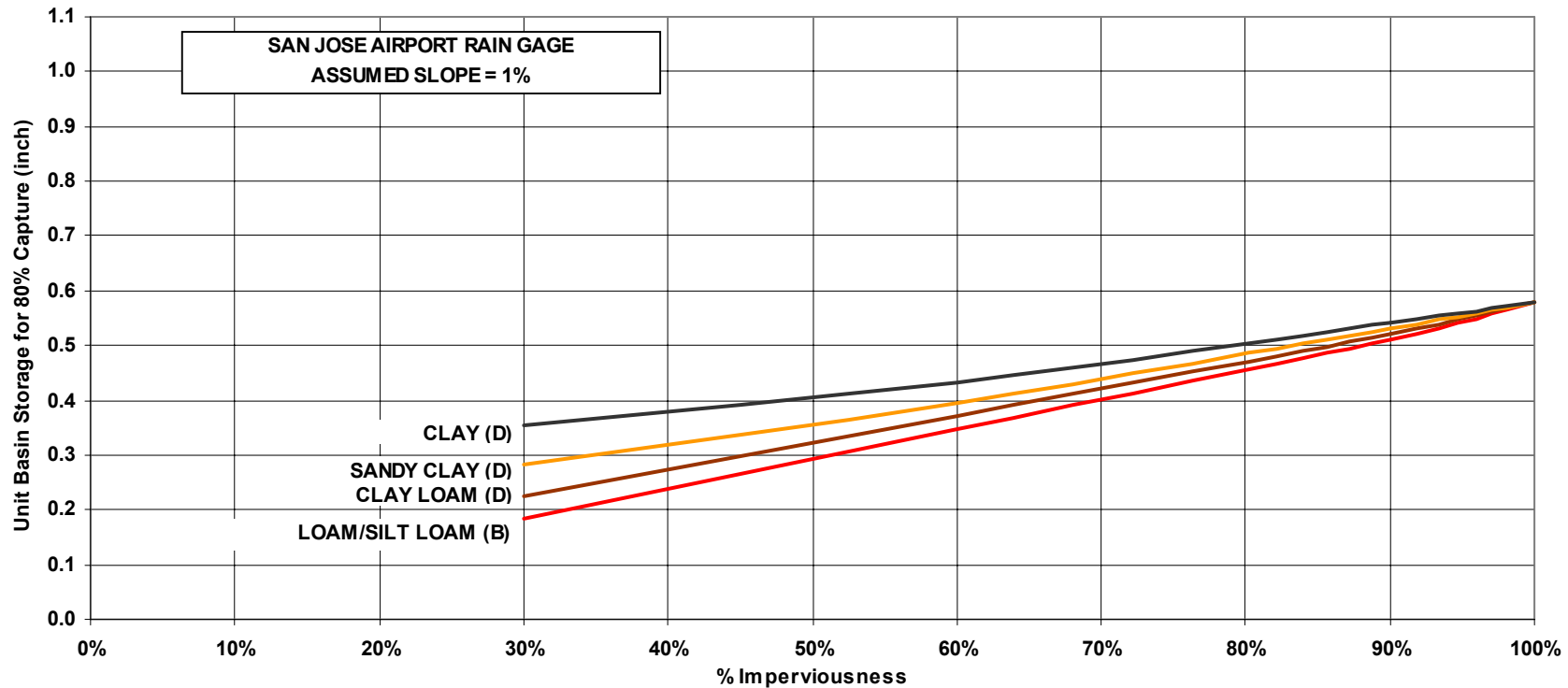


Figure 2-A Unit Basin Volume for 80% Capture - San Jose Airport Rain Gage

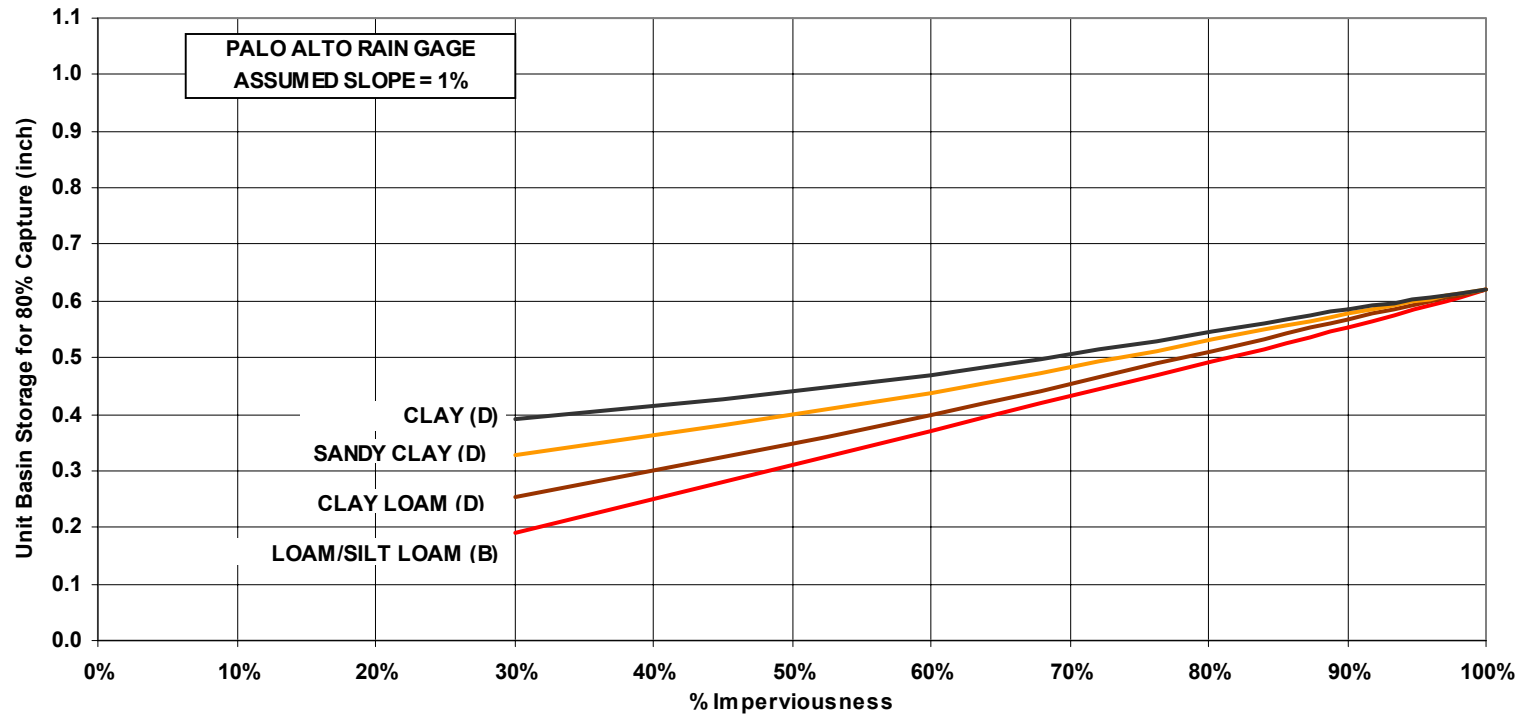
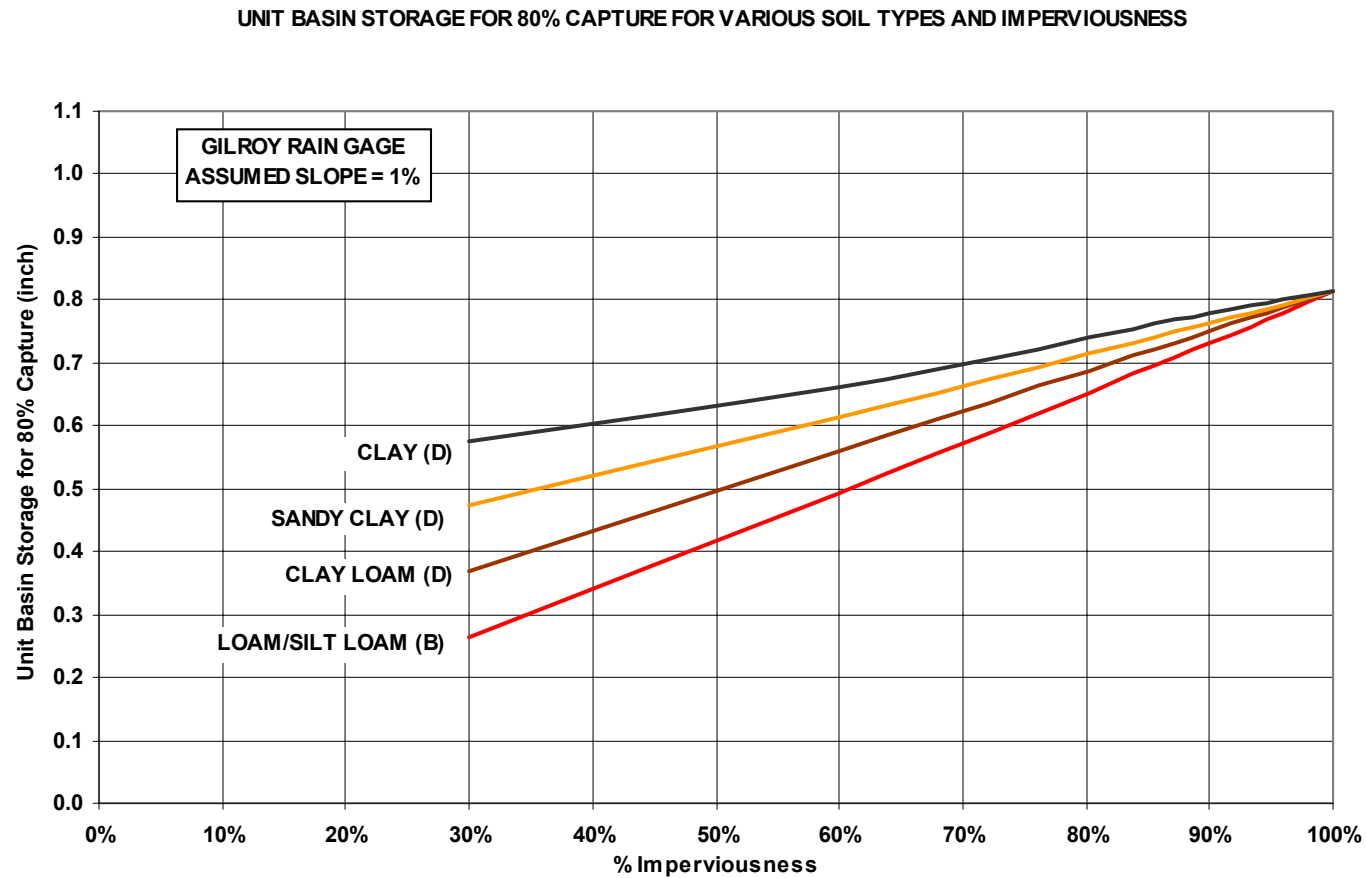


Figure 2-B Unit Basin Volume for 80% Capture - Palo Alto Rain Gage



**Figure 2-C Unit Basin Volume for 80% Capture - Gilroy Rain Gage**

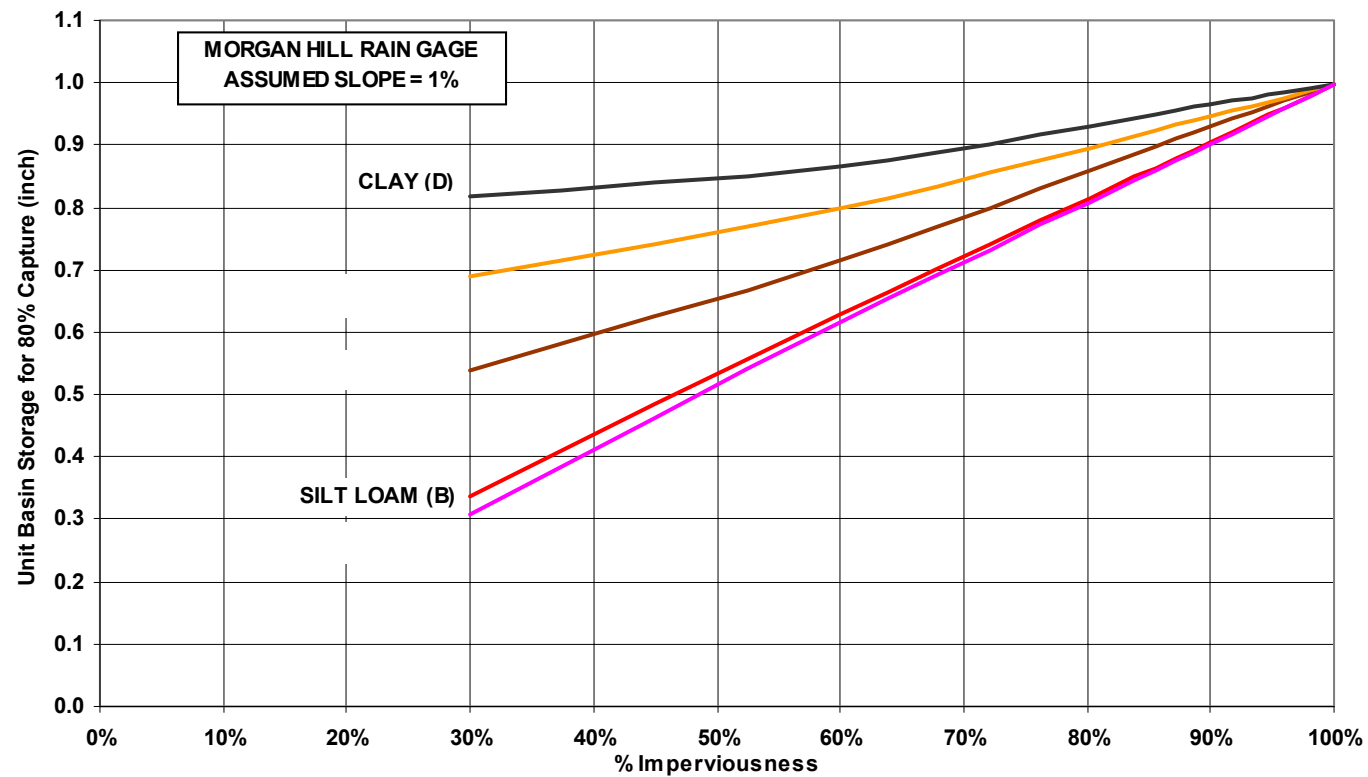


Figure 2-D Unit Basin Volume for 80% Capture - Morgan Hill Rain Gage

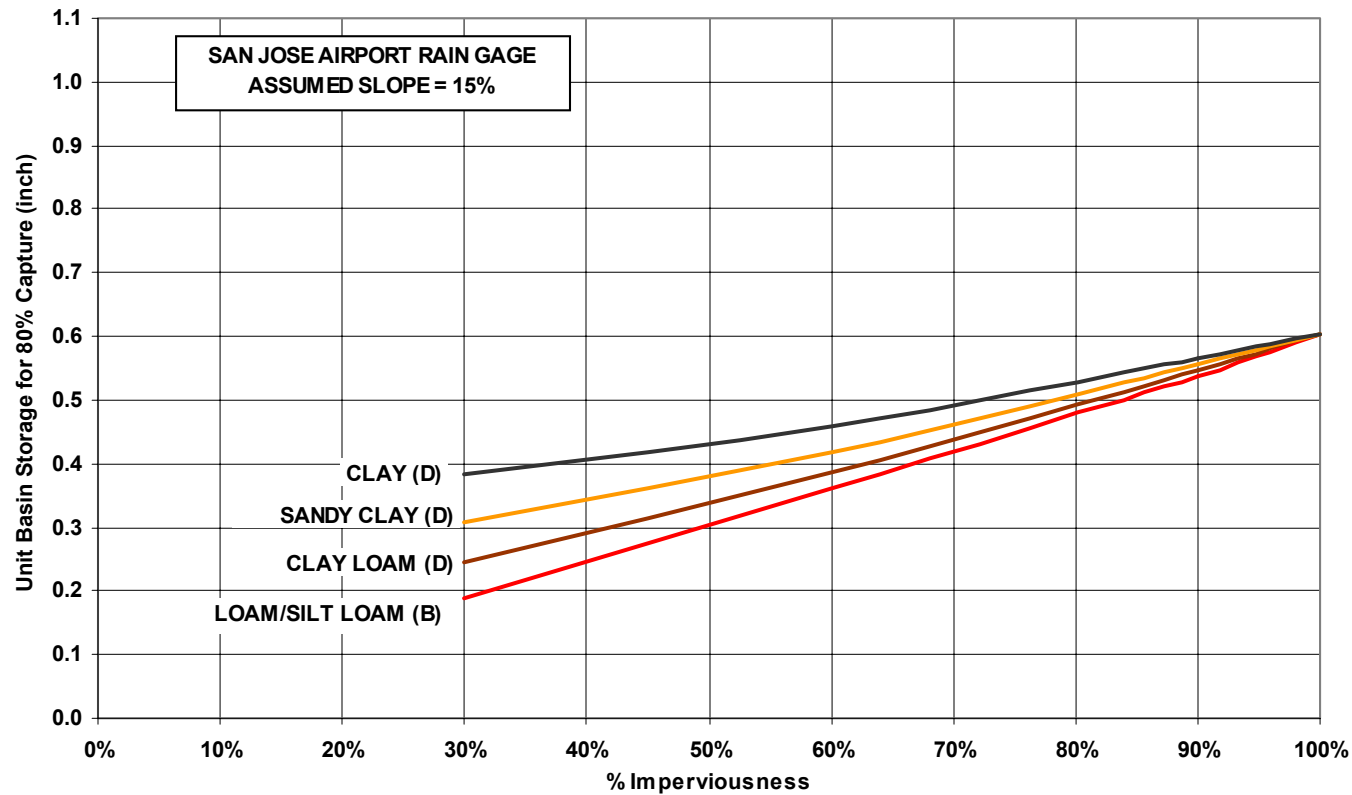


Figure 3-A Unit Basin Volume for 80% Capture - San Jose Airport Rain Gage

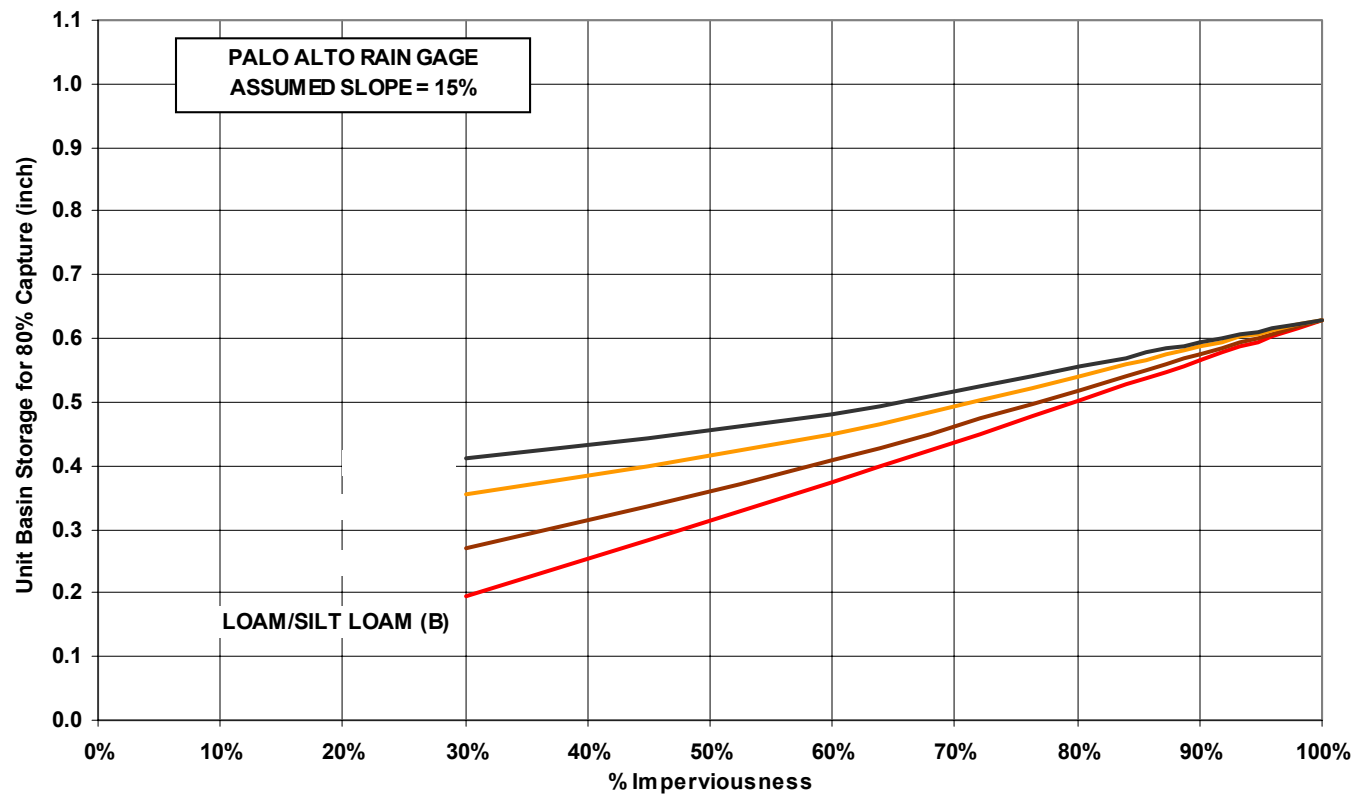


Figure 3-B Unit Basin Volume for 80% Capture - Palo Alto Rain Gage



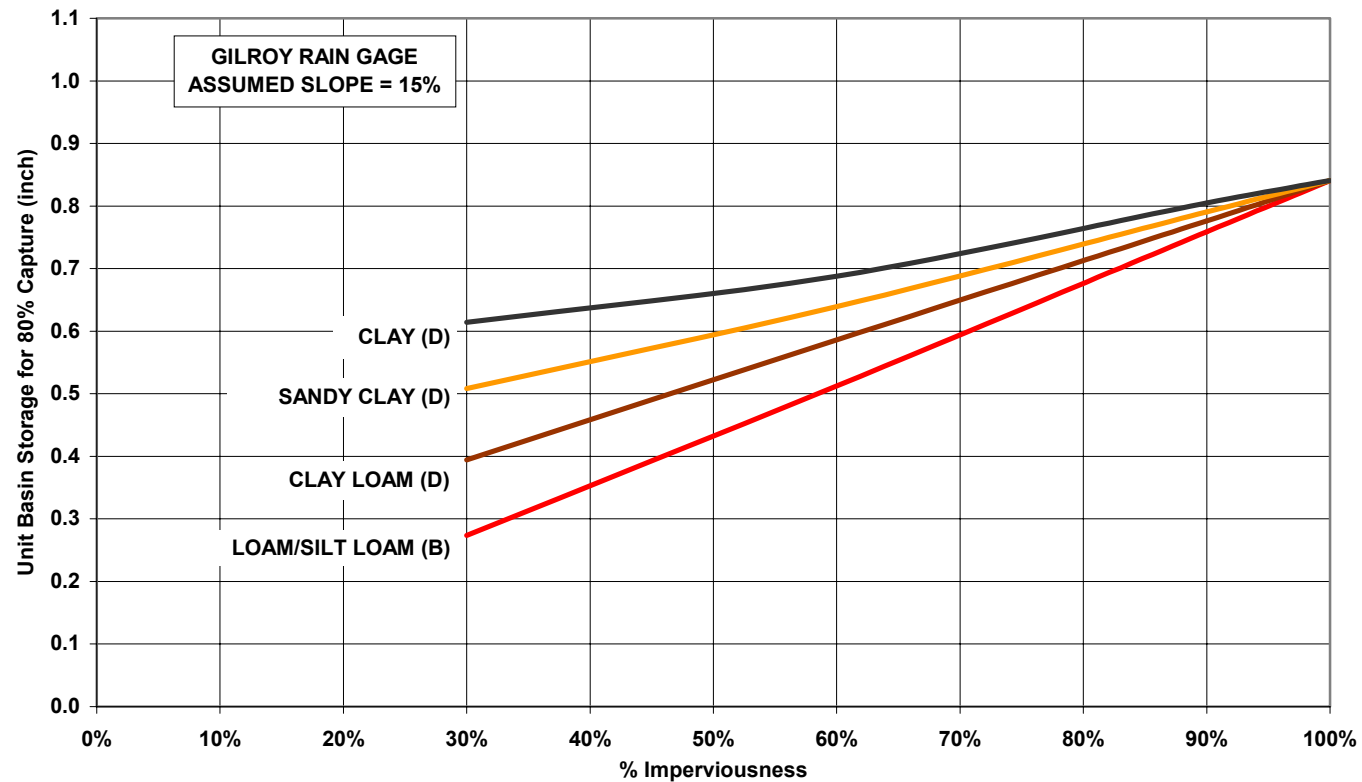


Figure 3-C Unit Basin Volume for 80% Capture - Gilroy Rain Gage

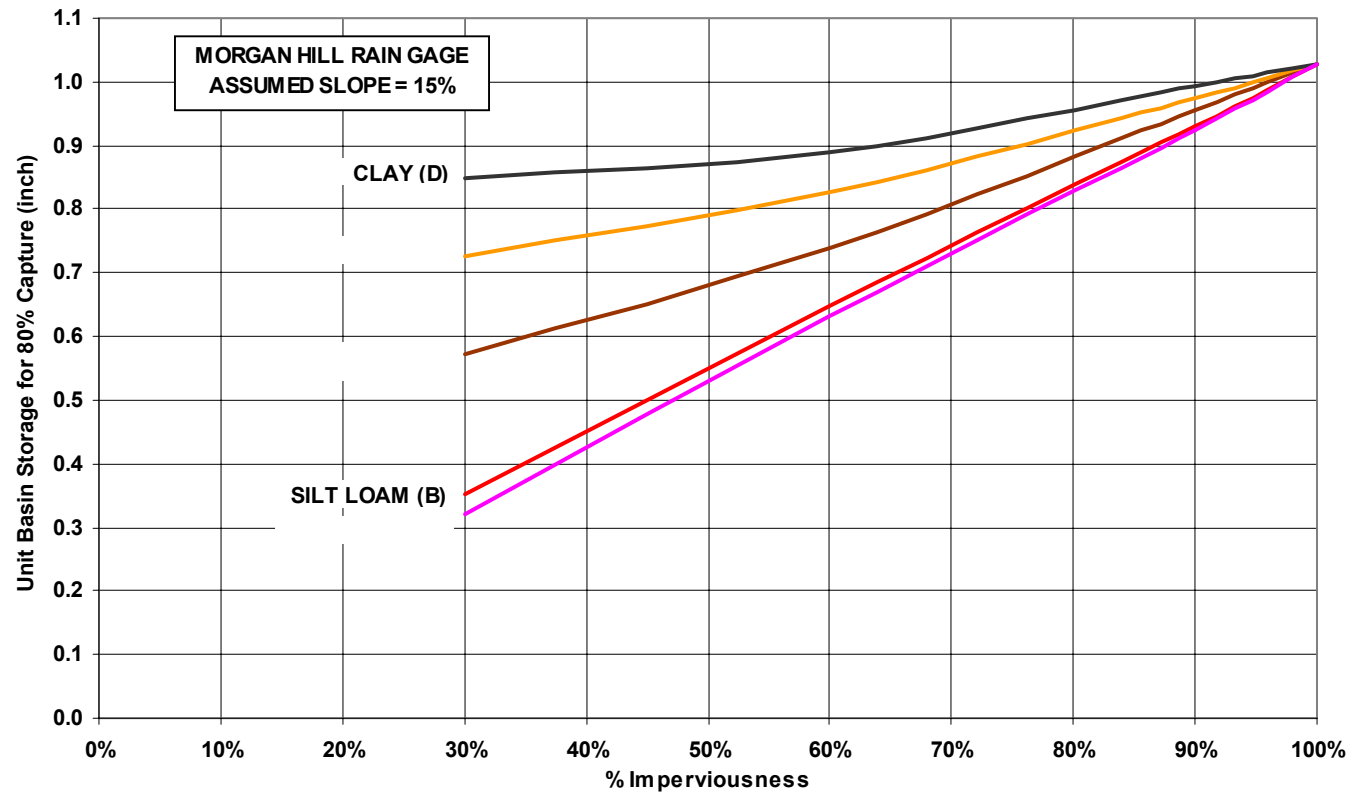


Figure 3-D Unit Basin Volume for 80% Capture - Morgan Hill Rain Gage

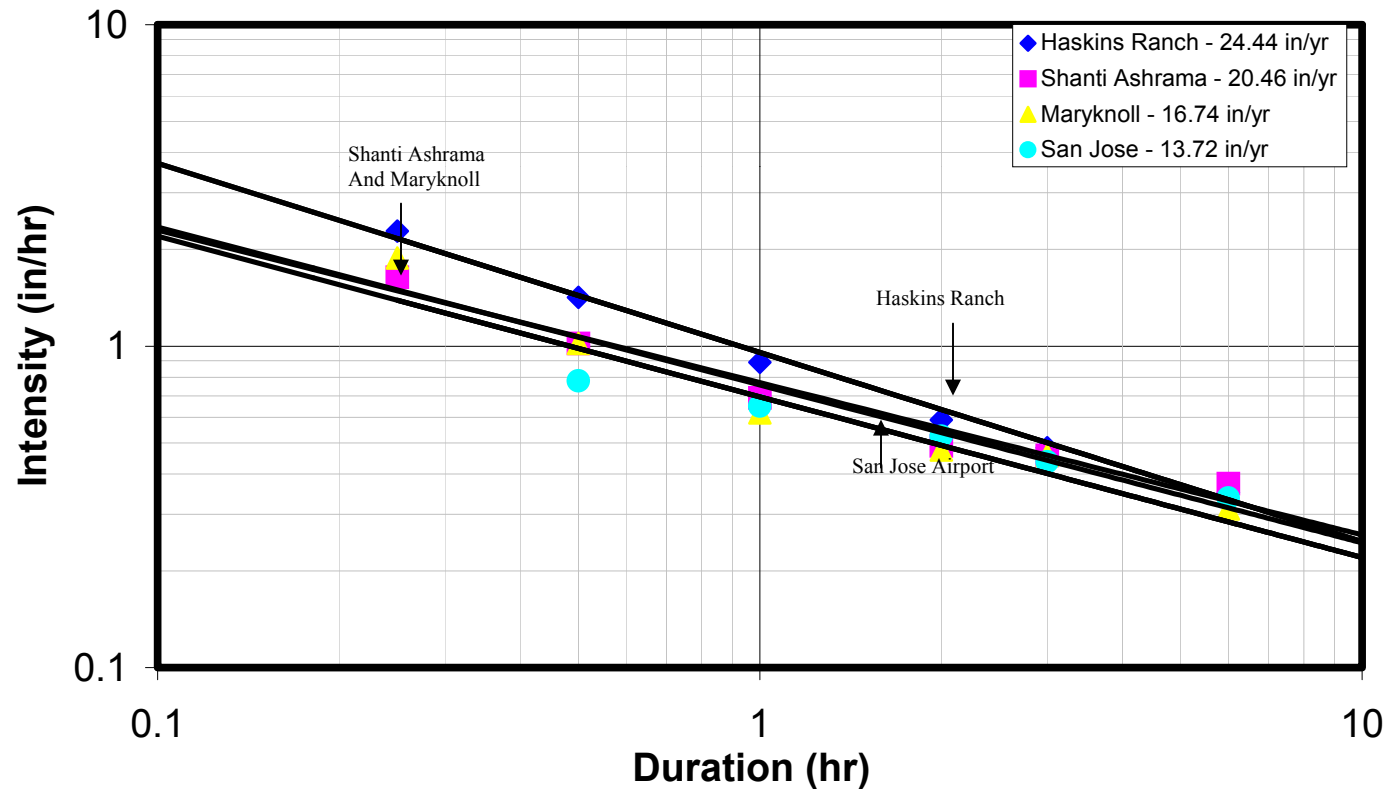


Figure 4 Intensity-Frequency-Duration Curves for a 50-Year Return Period for Haskins Ranch, Shanti Ashrama, Maryknoll, and San Jose Airport Rain Gages

## Attachment IV-2

### Residential Example Problems

#### *Single-Family Subdivision*

The following are examples of how to size treatment controls using the Sizing Criteria Worksheets (Attachment IV-1) as well as all of the figures and tables that can be found in Chapter IV of the C.3 Handbook. These examples demonstrate the calculations for sizing possible BMPs at an actual development site, a proposed single-family subdivision in the southeast end of the City of Santa Clara. It should be noted that the examples demonstrate how to size BMPs for two different components of the project: the paved public areas of the project in this case streets and the single family homes. In this example both types are needed for the project to comply. The conditions and results for the two analyses are summarized below.

**Given:** 10-acre (435,600 ft<sup>2</sup>) single-family subdivision with the following:

- 1-acre (43,560 ft<sup>2</sup>) proposed city park
- 131,040 square feet (30%) of pavement (paved public streets)
- 87 residences with:
  - 3,000 square feet per lot (261,000 ft<sup>2</sup>)
  - 130,500 square feet (50%) of rooftops
  - 39,150 square feet (15%) of walkways (includes patio areas)
  - 1% slope on-site

#### Example 1: Sizing for Volume-Based Controls

- Pavement (paved public streets) drain to one BMP
- Sizing for Volume-Based Controls

#### Example 2: Sizing for Flow-Based Controls

- Rooftop and walkway runoff for each lot drains to individual onsite BMPs
- Sizing for Flow-Based Controls

Table of Results

Example	BMP Size	Comments
1. Volume-Based	7,629 cubic feet	All public streets/sidewalks drain to one BMP
2. Flow-Based	0.0065 cfs (3 gal/min)	Each lot drains to individual onsite BMP

### Example 1: Sizing for Volume-Based Controls

**This example demonstrates use of the CA Stormwater BMP Handbook Volume Approach.**

**Given:** 10-acre (435,600 ft<sup>2</sup>) single-family subdivision with the following:

- 1-acre (43,560 ft<sup>2</sup>) proposed city park
- 131,040 square feet (30%) of pavement (paved public streets)
- 87 residences with:
  - 3,000 square feet per lot (261,000 ft<sup>2</sup> total)
  - 130,500 square feet (50%) of rooftops
  - 39,150 square feet (15%) of walkways (includes patio areas)
- 1% slope on-site

**Assume runoff from all pavement in public ROW drains to a detention basin in the park**  
(i.e., excluding private lot areas but including the park area)

**Task:** Determine BMP volume required to detain and treat stormwater runoff from pavement areas.

Step 1: Determine the drainage area for the BMP (A)

$$\begin{aligned}\text{Total Drainage Area to BMP} &= A \\ &= \text{Total Area} - \text{Areas draining to individual BMPs on each lot} \\ &= 435,600 \text{ ft}^2 - 261,000 \text{ ft}^2 (\text{lot area})\end{aligned}$$

$$= 174,600 \text{ ft}^2$$

Step 2: Determine percent imperviousness of the drainage area.

- a. Estimate the amount of impervious surface (streets, and sidewalks) in the area draining to the BMP.

$$\text{Total Impervious Area} = \text{Pavement Area}$$

$$= 131,040 \text{ ft}^2$$

- b. % impervious area = (amount of impervious area/drainage area for the BMP)\*100  
= (Step 2a/Step 1)\*100  
= (131,040 ft<sup>2</sup>/174,600 ft<sup>2</sup>)\*100

$$= 75\%$$

Step 3: Determine from Figure 2 the mean annual precipitation (MAP) at the project site location. The subdivision is located between the isopleths with values of 14 and 15. A value of 14.9 is estimated from the figure.

$$\text{MAP}_{\text{site}} = 14.9 \text{ inches}$$

Step 4: Identify the rain gage closest to the project site from the following list:

$$\text{San Jose Airport MAP}_{\text{gage}} = 13.9 \text{ in}$$

Step 5: Determine the rain gage correction factor for the precipitation at the site using the information from **Step 3** and **Step 4**.

$$\text{Correction Factor} = \text{MAP}_{\text{site}} (\text{Step 3}) / \text{MAP}_{\text{gage}} (\text{Step 4})$$
$$= 14.9 \text{ inches} / 13.9 \text{ inches}$$

$$= 1.07$$

Step 6: Identify representative soil type for BMP drainage area

- a. Identify from Figure 1 (Attachment IV-1) the soil type that is representative of the pervious portion of the project: (in order of increasing infiltration capability)

\_\_\_ Clay \_\_\_ Sandy Clay \_\_\_ Clay Loam X Silt Loam \_\_\_ Loam

- b. Does the site planning allow for protection of natural areas and associated vegetation and soils so that the soils outside the building footprint are not graded/compacted? No

If your answer is no, and the soil will be compacted during site preparation and grading, the soil's infiltration ability will be decreased. Consider modifying your answer to a soil with a lower infiltration rate (e.g., Silt Loam to Clay Loam or Clay).

Modified soil type: Clay

Step 7: Determine the average slope for the drainage area for the BMP: 1%

Step 8: Determine the unit basin storage volume from sizing curves.

- a. Slope  $\leq 1\%$  or less

Use Figure 3-A "Unit Basin Volume for 80% Capture, 1% Slope" corresponding to the nearest rain gage in San Jose. Find the % imperviousness of the drainage area (see answer to **Step 2**, above) on the x-axis. From there, find the line corresponding to the soil type (from **Step 6**), and obtain the unit basin storage on the y-axis.

For this example, with 75% imperviousness and a clay soil type the Unit Basin Storage is.

$$\text{Unit Basin Storage} = 0.49 \text{ (inches)}$$

Step 9: Size the BMP

The BMP volume is calculated by multiplying the correction factor by the unit storage volume by the drainage area.

$$\begin{aligned} \text{BMP Volume} &= \text{Rain Gage Correction Factor} * \text{Unit Basin Storage Volume} * \text{Drainage Area} \\ &= (\text{Step 5}) * (\text{Step 8}) * (\text{Step 1}) \\ &= 1.07 * 0.49 \text{ inches} * 174,600 \text{ ft}^2 * (1 \text{ foot} / 12 \text{ inches}) \end{aligned}$$

$$\text{BMP Volume} = 7,629 \text{ cubic feet}$$

⇒ **Volume-based BMP controls will be sized to provide 7,629 cubic feet of storage for stormwater treatment.**

## Example 2: Sizing for Flow-Based Controls

**This example demonstrates use of the Calif. Stormwater BMP Handbook Flow Approach.**

**Given:** 10-acre (435,600 ft<sup>2</sup>) single-family subdivision with the following:

1-acre (43,560 ft<sup>2</sup>) proposed city park

131,040 square feet (30%) of pavement (paved public streets)

87 residences with:

3,000 square feet per lot (261,000 ft<sup>2</sup>)

1,500 square feet per lot (50%) of rooftops

450 square feet per lot (15%) of walkways (includes patio areas)

1% slope on-site

**Assume that runoff from each lot drains to a separate BMP on the lot**

**Task:** To determine the BMP flow required to effectively treat stormwater runoff.

Step 1. Determine the drainage area for the BMP (A)

Total Drainage Area to BMP = 3,000 ft<sup>2</sup> =

0.0689 acres

Step 2a: Estimate the amount of impervious surface (rooftops, hardscape, streets, and sidewalks, etc.) in the area draining to the BMP.

Total Impervious Area = Roof Area + Walkway Area

= 1,500 ft<sup>2</sup> + 450 ft<sup>2</sup>

= 1,950 ft<sup>2</sup>

Note: Although each individual lot does not exceed 43,560 ft<sup>2</sup> (or 1 acre); the combination of impervious area in the 87 units in the subdivision does trigger BMP requirements. In this exercise, the individual lot BMP is being sized.

Step 2b: Determine the runoff coefficient, "C", from the Tables 3a. and 3.b. in the C.3 Handbook.

Compute an area-weighted average of the "C" for the impervious and pervious surfaces. For roofs and concrete walkways, assume a "C" of 0.75; for the remaining portion of the lot (grass and landscaping), assume a "C" of 0.10.

$$C = [(1,950 * 0.75) + (1,050 * 0.10)] / 3,000 = 0.52$$

C = 0.52

Step 4: Determine from the figure in Attachment V-3 of the C.3 Manual the mean annual precipitation (MAP) at the project site location. The subdivision is located between the isopleths with values of 14 and 15. A value of 14.9 is estimated from the figure.

MAP<sub>site</sub> = 14.9 inches

Step 5: Determine the mean annual rainfall at the gage closest to the site:

$$\text{San Jose Airport MAP}_{\text{gage}} = 13.9 \text{ in}$$

Step 6: Determine the rain gage correction factor for the precipitation at the site using the information from **Step 4** and **Step 5**.

$$\text{Correction Factor} = \text{MAP}_{\text{site}} (\text{Step 4}) / \text{MAP}_{\text{gage}} (\text{Step 5})$$

$$\text{Correction Factor} = 14.9 \text{ inches} / 13.9 \text{ inches}$$

$$= \underline{1.07}$$

Step 7: Identify the gage closest to the site from the following list to determine I, the design intensity:

Gages	85 <sup>th</sup> Percentile Hourly Rainfall Intensity (in/hr)	Design Rainfall Intensity (I) (in/hr)
San Jose Airport	0.087	<b>0.17</b>
Palo Alto	0.096	0.19
Gilroy	0.11	0.21
Morgan Hill	0.12	0.24

Step 8. Determine the corrected design rainfall intensity (I) for the site:

$$\text{Design intensity (site)} = \text{Correction factor} * \text{Design rainfall intensity for closest rain gage}$$

$$= (\text{Step 6}) * (\text{Step 7})$$

$$= 1.07 * (0.17 \text{ inches/hour})$$

$$= \underline{0.182 \text{ inches/hour}}$$

Step 9. Determine the design flow (Q) using the Rational Method equation

$$Q = C * I * A$$

$$Q = (\text{Step 3}) * (\text{Step 8}) * (\text{Step 1})$$

$$Q = (0.52) * (0.182 \text{ in/hr}) * (0.0689 \text{ acres})$$

$$Q = \underline{0.0065 \text{ cfs (approx. 3 gallons per minute)}}$$

⇒ **Flow-based BMP controls will be sized to treat a flow of 0.0065 cfs of stormwater for each lot.**